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THE STORMY FUTURE OF WEATHER FORECASTING

By GODE DAVIS

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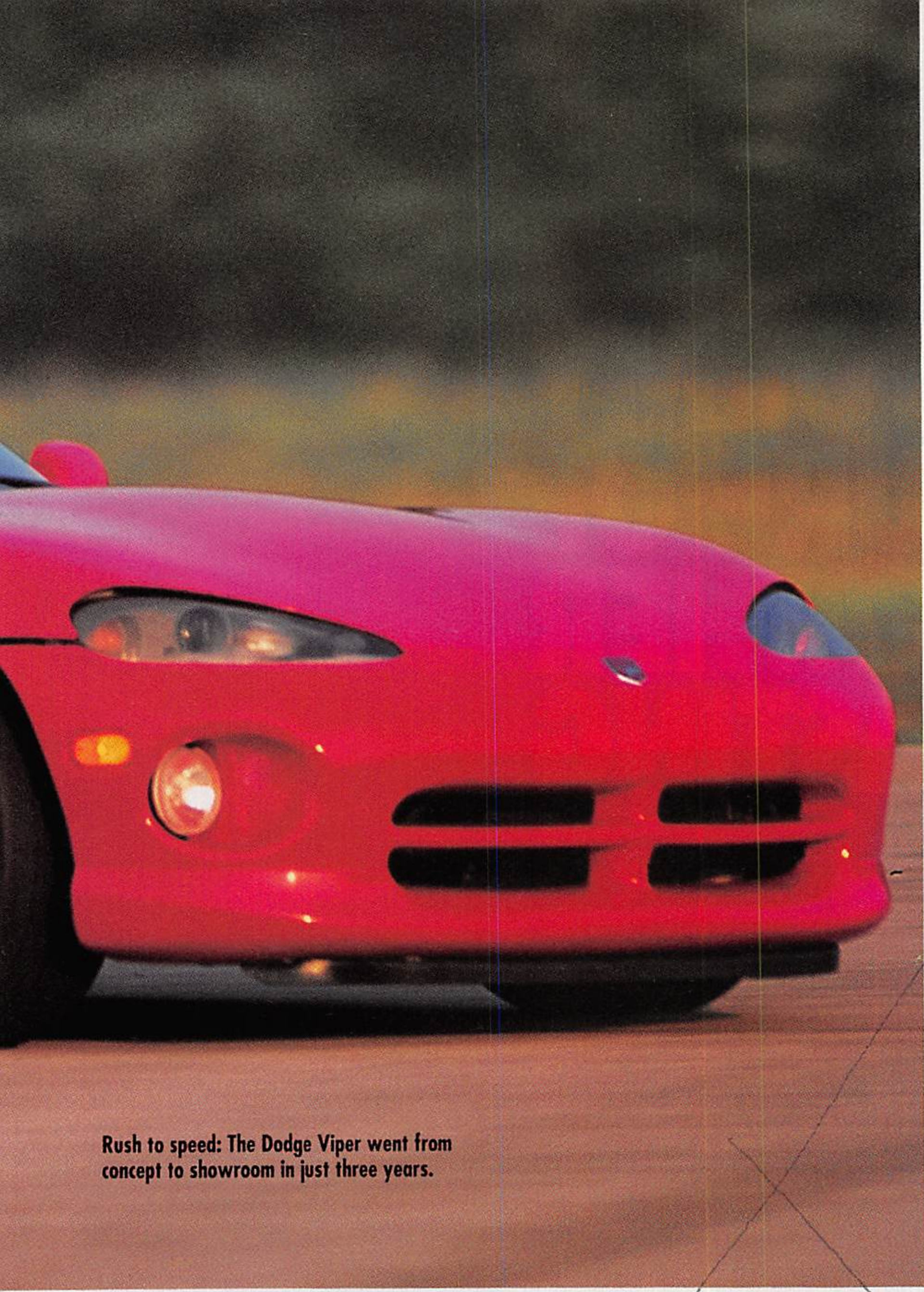

Rush to speed: The Dodge Viper went from concept to showroom in just three years.

JOHN B. CARNETT

VIPER VS. CORVETTE

SPECIFICATIONS	DODGE VIPER	CHEVROLET ZR-1 CORVETTE
BODY TYPE	ROADSTER	COUPE
OVERALL LENGTH	175.0 IN.	178.5 IN.
WHEEL BASE	96.0 IN.	96.2 IN.
OVERALL HEIGHT	45.0 IN.	46.7 IN.
OVERALL WIDTH	75.0 IN	74.0 IN.
CURB WEIGHT	3,200 LBS.	3,465 LBS.
ENGINE TYPE	OHV 2-VALVE V10	DOHC 4-VALVE V8
BORE	4.0 IN.	3.90 IN.
STROKE	3.88 IN.	3.66 IN.
HORSEPOWER	400 @ 5,000 RPM	375@5,800 RPM
TORQUE	450 @ 3,500	370 @4,800
TRANSMISSION	6-SPEED MANUAL	6-SPEED MANUAL
TIRES-FRONT/REAR	P275/40-ZR17 P335/35-ZR-17	P275/40-ZR17 P315/35-ZR-17
PRICE	$50,000-$60,000	$59,000

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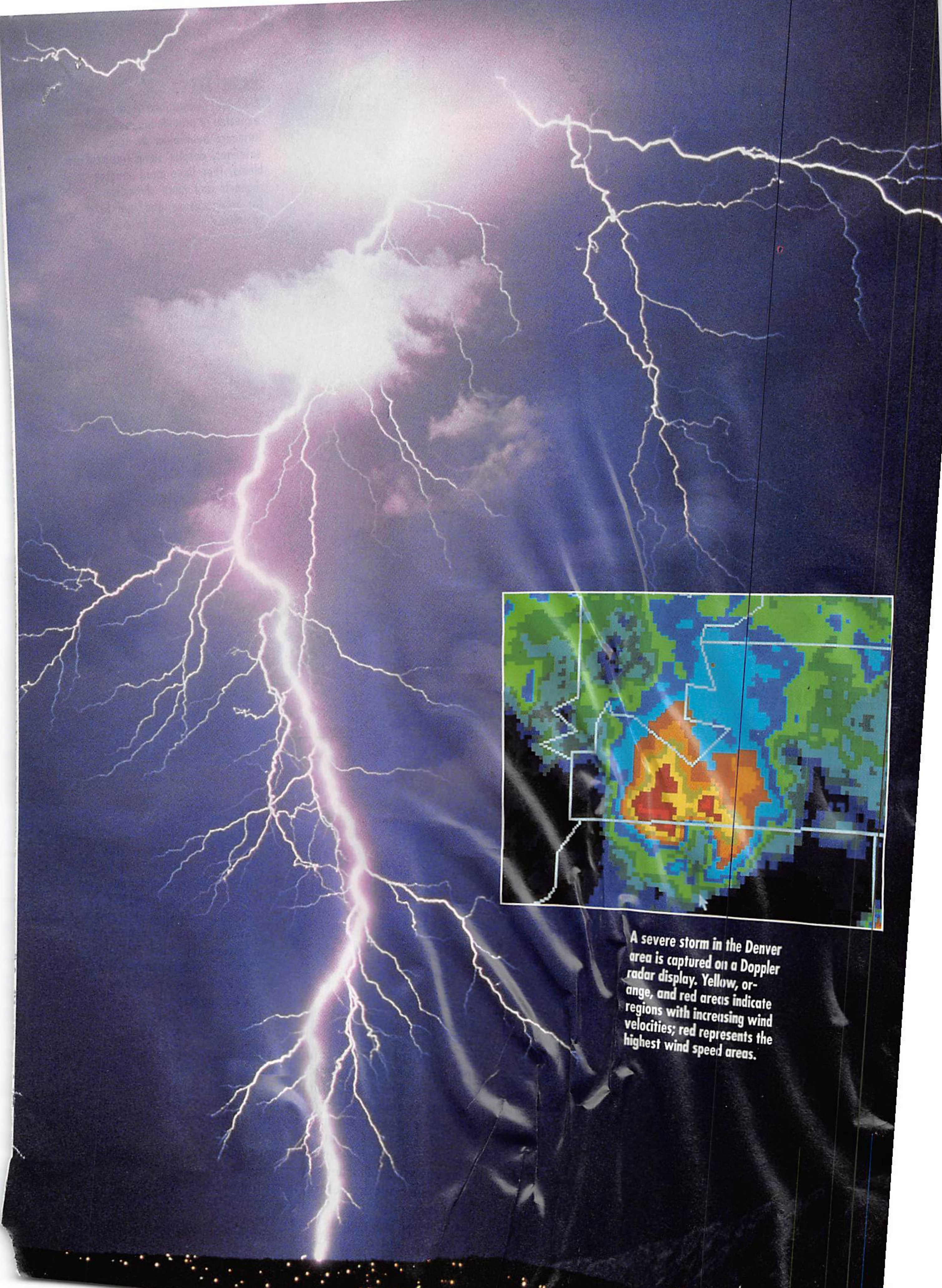

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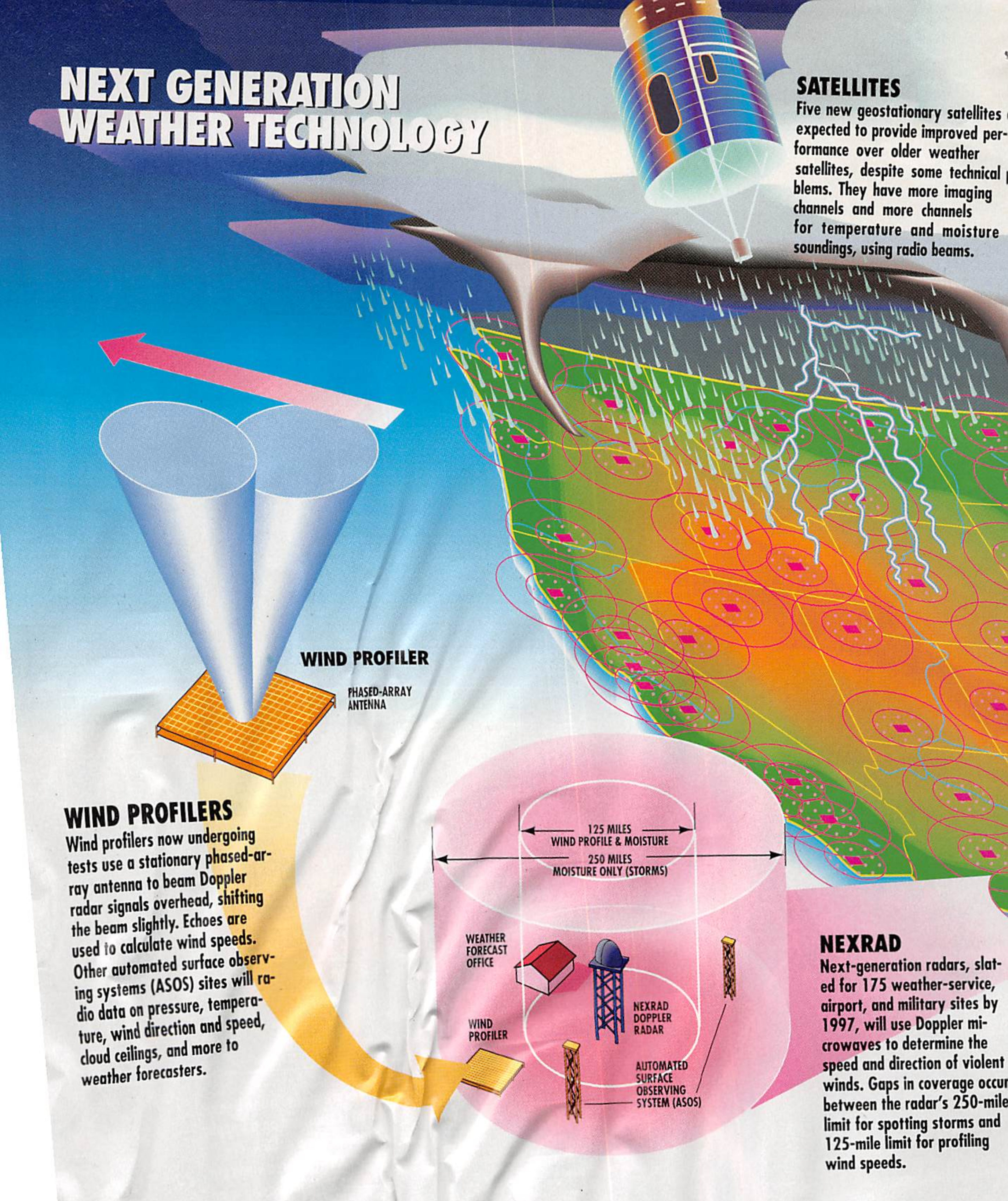
NEXT GENERATION WEATHER TECHNOLOGY



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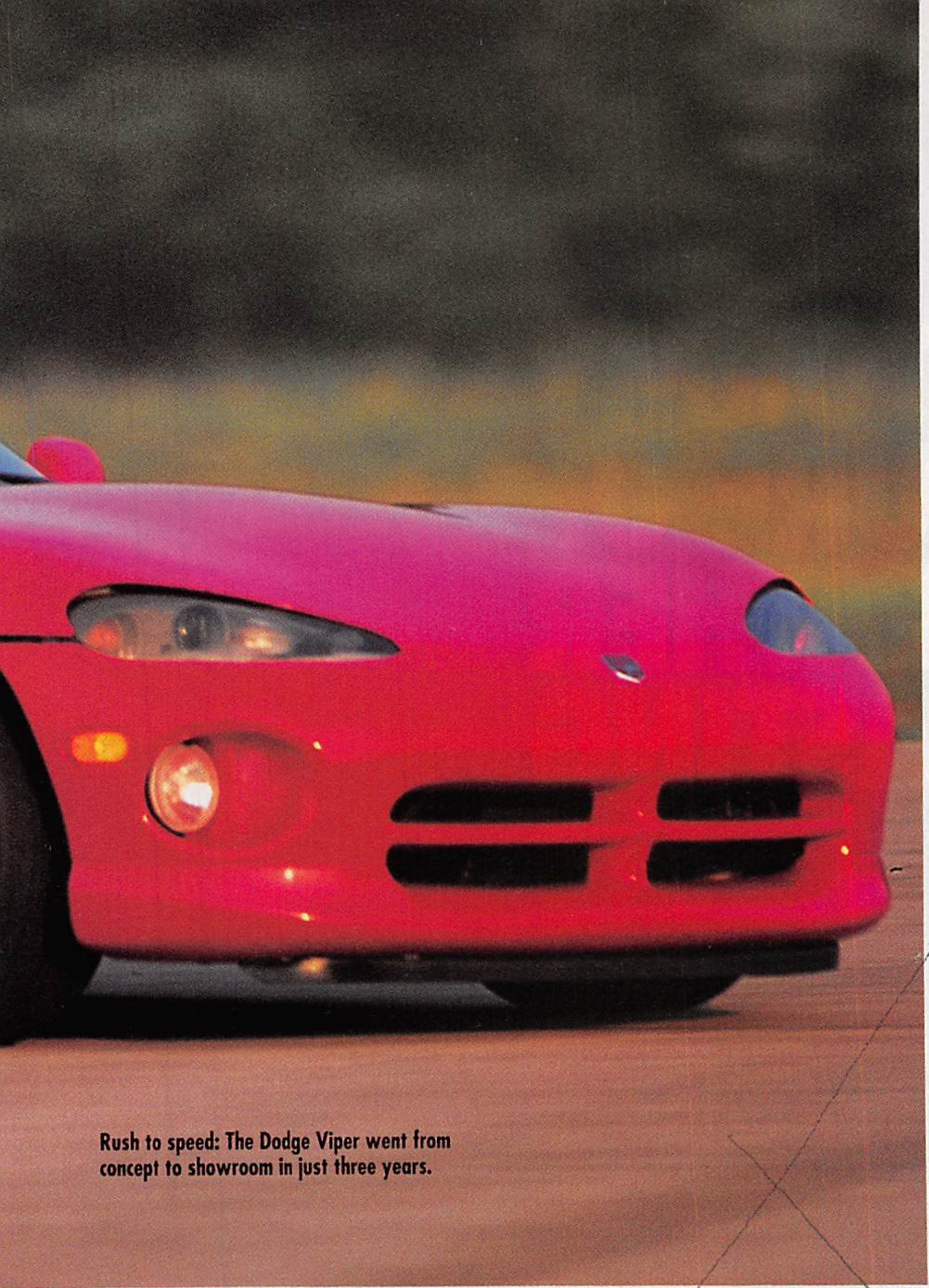

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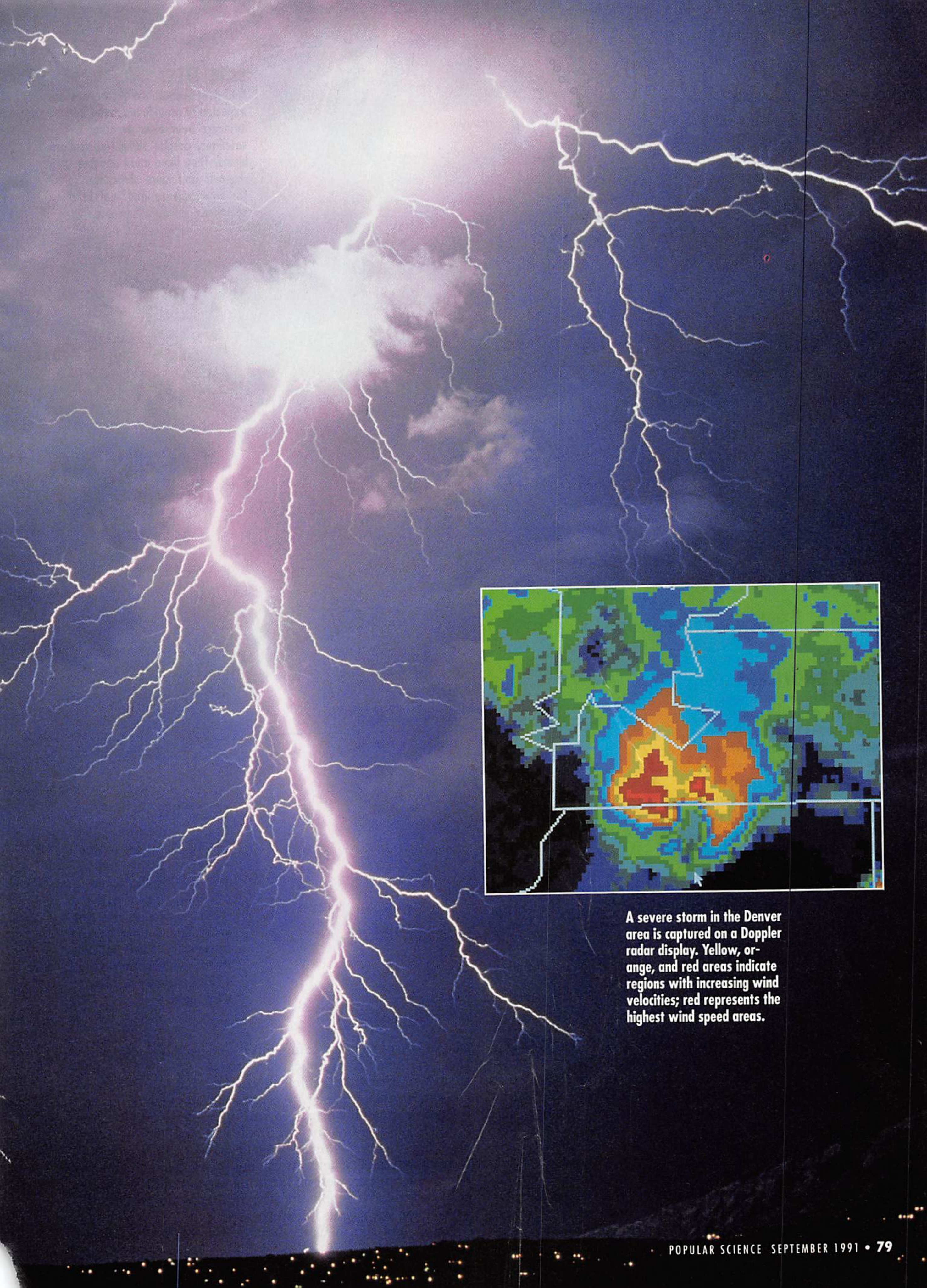

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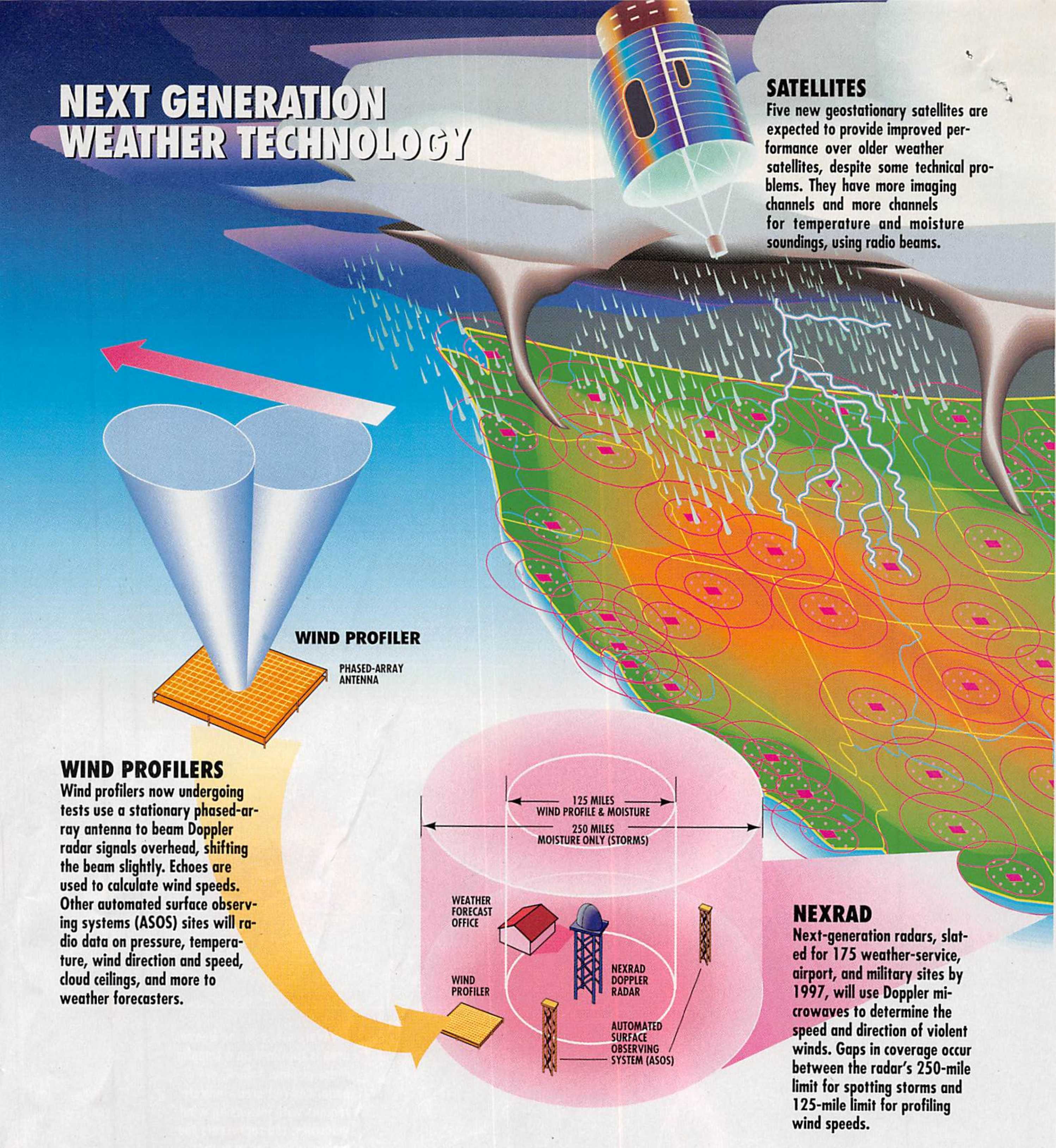

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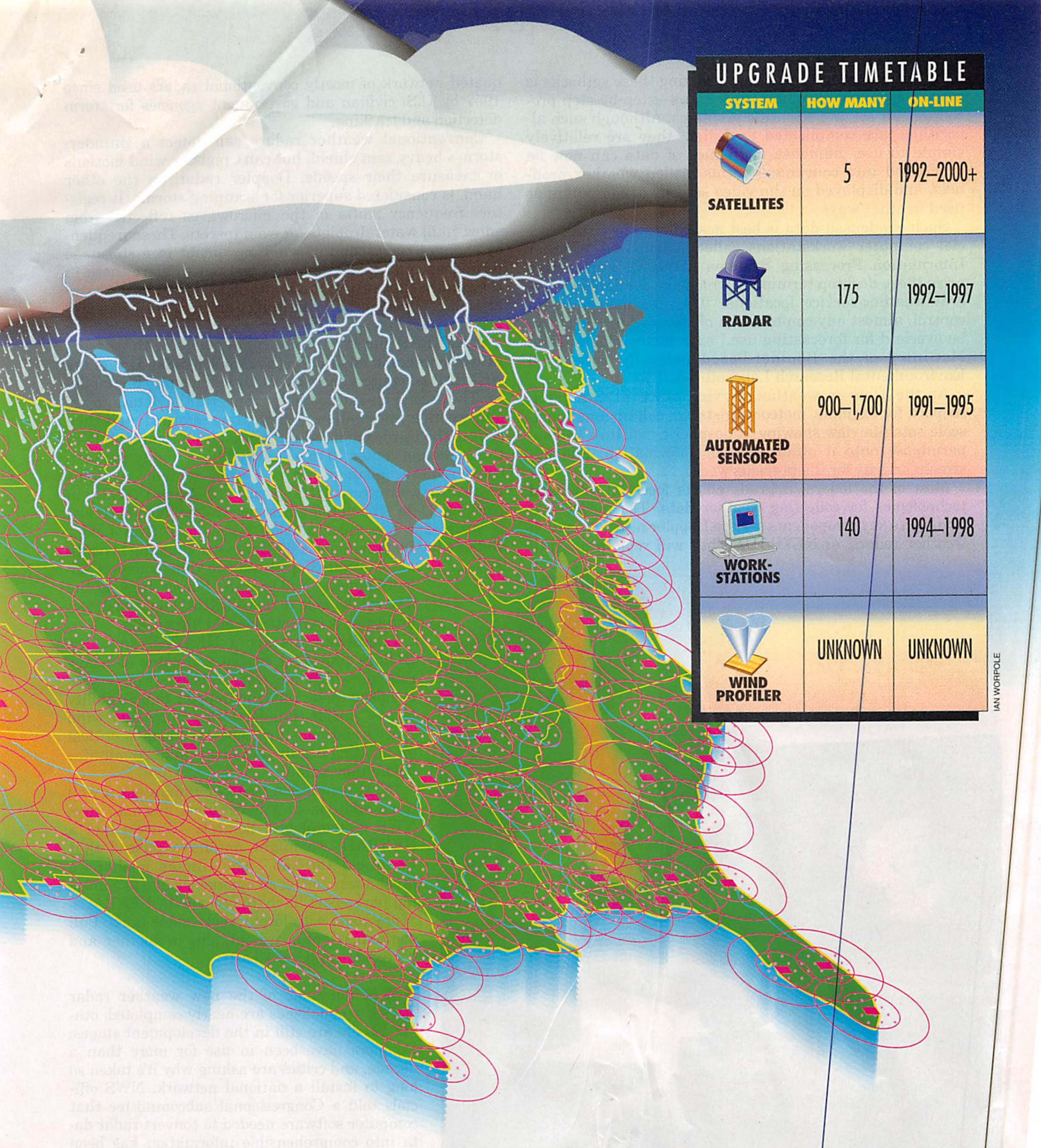


UPGRADE TIMETABLE

SYSTEM	HOW MANY	ON-LINE
SATELLITES	5	1992–2000+
RADAR	175	1992–1997
AUTOMATED SENSORS	900–1,700	1991–1995
WORK-STATIONS	140	1994–1998
WIND PROFILER	UNKNOWN	UNKNOWN

IAN WORPOLE

They were cresting a Ferris wheel 100 feet off the ground when plum-size hailstones began falling. Fifteen-year-old Aaron wrapped his arms around his younger sister to protect her head and glasses from the pounding ice. The hail raised welts all over Aaron's body and broke the skin on his forearms. "I was just praying," Aaron said later.

The Elitch Gardens ordeal can't be blamed on bad meteorology. In fact, Colorado's Denver-Boulder area is a well-known weather-technology proving ground. Denver forecasts are quite refined because local meteorologists have numerous resources for prediction.

Accurate weather predictions depend on gathering information from sensor networks and feeding the data into computerized grids that simulate the atmosphere on large (synoptic) or smaller (meso) scales. Meteorologists then study the grids, trying to figure out the atmosphere's next move.

During the 1980s, new technologies for observing the atmosphere enabled meteorologists to gather more information than ever before. However, the enormous amount of data collected has now made weather prediction even more complicated. Because of primitive computer software still used at local stations, frustrated meteorologists can't benefit from much of the additional weather data for their forecasts.

One of the technologies counteracting these setbacks is a system of new computer algorithms—step-by-step procedures for solving scientific problems. Although such algorithms are complicated to design, they are relatively simple to use. Immense quantities of data can now be condensed into convenient forms, called weather products, and displayed on the video screens of computers or used in other ways.

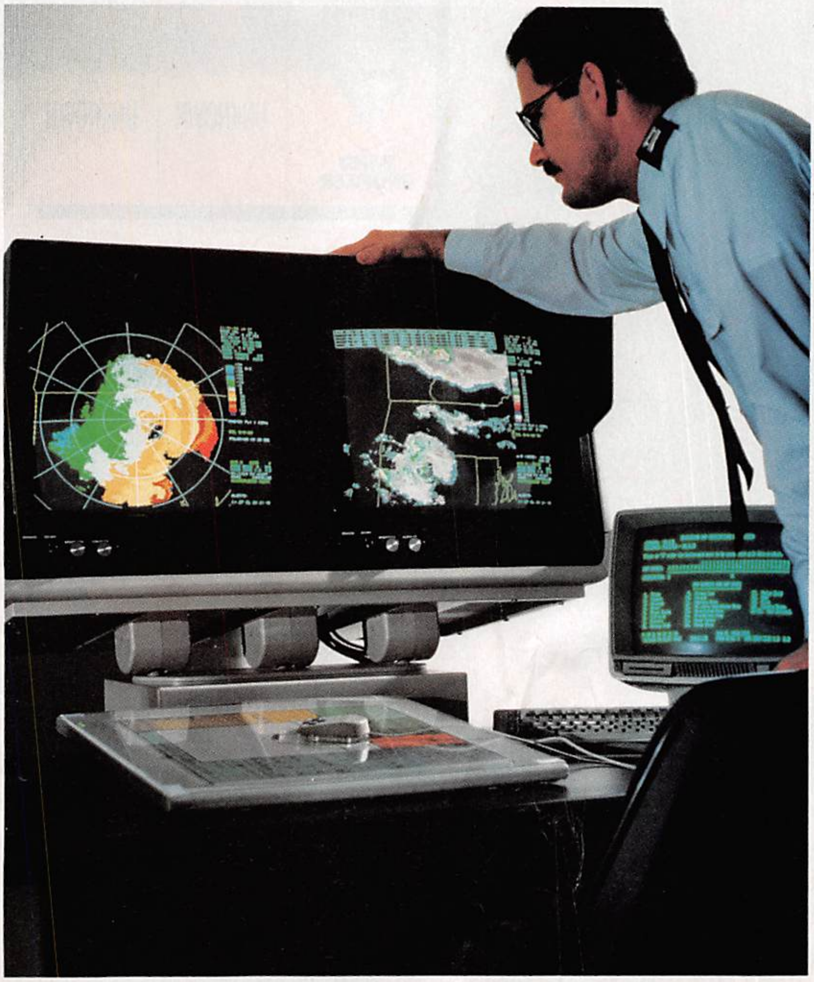
Such condensed data is best assimilated by using special computer workstations called Automated Weather Information Processing Systems (AWIPS). Forecasters prize these desktop terminals, which are available at several weather-service locations. "Using a mouse-driven control, almost any combination of weather products can be overlaid for forecasting use," says meteorologist John McGinley of the Boulder-based federally sponsored Environmental Research Laboratories (ERL).

At the Denver weather service office at Stapleton Airport, for example, meteorologists can call up a national-scale satellite view showing atmospheric moisture and superimpose onto it other weather information, like jet-stream activity for the previous week.

Most of the federal upgrade efforts focus on advanced technologies for collecting weather data. The modernization plan's key components are the Doppler next-generation weather radars, or NEXRADs. They will replace an antiquated network of mostly conventional radars used since 1957 by U.S. civilian and government agencies for storm detection and tracking.

Conventional weather radars can detect a thunderstorm's heavy rain shield, but can't register wind motions or measure their speeds. Doppler radar, on the other hand, is considered superior for scanning storms. It registers frequency shifts in the microwaves reflected from snow, hail, water droplets, or even insects. These frequency changes correspond to wind movement in a storm, so tornadoes can be revealed and tracked to alert those in their paths. Because of the limitations of standard weather radar, visual tornado sightings are usually needed to provide warnings.

A NEXRAD site is part of a chain involving three separate computers in addition to the Doppler radar. One of the NEXRAD computers converts radar signals into digital data. The second on-site computer converts the data into usable weather information. This weather information is then sent to the third computer and workstation combination at the command center 10 miles away. "It's a highly sophisticated radar-acquisition and processing system," explains Ron Alberty, director of the operational support facility in Norman, Okla. The nation's first operational NEXRAD site is situated a few miles outside Norman at Twin Lakes. Outside the installation is a 60-foot tower standing beneath a volleyball-shaped radome that houses a 26-foot-diameter radar dish. Forecasters at the site will be able to use NEXRAD data to detect and track severe storms and hurricanes.



Advanced weather interactive processing systems (AWIPS) will be the nerve centers of the upgraded weather service program. These workstations, linked to high-speed computers, are part of a network collecting local weather data and integrating it with information from satellites.

Thunderstorms are a NEXRAD specialty. Besides providing crucial estimates of heavy rainfall, which may warn forecasters of dangerous flood conditions, the Doppler radar's ability to "see" inside thunderstorms to register wind speeds and moisture concentrations is critical for spotting deadly tornadoes up to 20 minutes before they strike.

"Next-generation weather radars are a welcome addition to a forecaster's arsenal," says NWS meteorologist Somrek. "If we'd had a NEXRAD, we might not have missed that Plainfield tornado." The Illinois mishap—a breakdown during an emergency due to a missing part—isn't likely to occur with NEXRADs. "They come with locally replaceable units. Pull one component board out, plug in another, and it's fixed," explains Alberty.

While some of the new weather radar technologies are nearly completed, others are still in the development stages; Dopplers have been in use for more than a decade, and critics are asking why it's taken so long to install a national network. NWS officials told a Congressional subcommittee that computer software needed to convert radar data into comprehensible information has been the leading cause of delays. Unisys, the NEXRAD contractor, claims that most criticism of its work has been based on mid-1989 tests of pre-production equipment.

Another reason for project delays: Weather equipment modernization, including NEXRAD, is a team effort involving three federal agencies: the Department of Commerce's NWS, the Federal Aviation Administration (FAA), and the Department of Defense. "Some of the delays are understandable. When each team has a different mission, some inevitable give-and-

take has to result," says Crawford.

The NWS has talked with Raytheon Corp. about building NEXRADs, threatening to drop Unisys as the lead contractor, even though it could lead to further delays, and perhaps the loss of lives in weather disasters. Raytheon is already building a separate Doppler radar system for the FAA. This system, slated for installation at commercial airports around the country within the next few years, will alert controllers and pilots to hazardous weather and wind shear within six miles of airports.

Another concern about the new Doppler-radar systems is what Alberty refers to as "the unreasonable fear of perceived radiation dangers." Citizen groups like MARK (Mothers Against Radiating Kids) prevented prototype NEXRADs from being placed at two proposed sites. "People are equating chromosome-altering gamma radiation with our radar system's microwave radiation. But the power density at any particular point from this radar is so low as to be almost undetectable by even the most sophisticated instruments," says Alberty.

If NEXRADs can be faulted, it's because they can't provide a forecaster with all necessary information. By themselves, the new radars would leave gigantic holes in any grid of a simulated atmosphere. Each NEXRAD radar system, surrounded by its neighbors, can extend its full-force beam approximately 125 miles. Unfortunately, the 175 radars covering the contiguous United States will be at least 200 miles apart in some areas. Also, a NEXRAD's Doppler beam is affected by the earth's curvature. Like any Doppler radar, a NEXRAD beam starts out narrow and concentrated, but farther out, because the earth is curving away from the beam, it is dispersed and at steeper angles. "Small low-forming tornadoes could slip beneath the beam and be missed as close as forty miles out," explains Don Sarreals, senior meteorologist at the NEXRAD program headquarters located near Washington, D.C.

NEXRADs aren't designed to observe anything but a slice of atmospheric winds and rainfall properties, sensing wind motions only within two miles of earth's surface. They don't detect high-elevation winds, including the jet-stream winds that usually steer American storms.

Part of NEXRAD's information gap can be filled with a special-purpose Doppler radar called a wind profiler. The profiler senses winds from about 1,600 feet above the ground up to about 55,000 feet. A profiler is not a scanning radar. "It simply points a beam vertically above [itself], tilts the beam fifteen degrees, and measures the wind components," says Don Beran, director of the Boulder-based profiler program. A comparison of these beam readings registers upper air wind directions and velocities. By themselves, these sensors have only limited applications, but a 30-unit wind-profiler demonstration network is being installed in 15 Midwestern states.

Without a wind-profiler network, meteorologists have had to depend primarily on a network of weather balloons equipped with radiosondes launched twice a day to record essential upper atmosphere data. "The profiler literally does what a radiosonde does," says Beran, "but instead of getting radiosonde data every twelve hours, we can get profiler data every hour." Unfortunately, while a network of profilers should complement NEXRAD-obtained wind data, wind profilers probably won't replace the infrequent radiosonde readings. That's because the sensors carried in the weather balloons don't just measure wind, they also sample atmospheric temperature and humidity.

Because upper air data is so important for forecasts, researchers are trying to make profiling Dopplers more versatile. One way to accomplish this might be with an experimental device that can be added on to the vertically pointing radars. This thermodynamic profiler, called a Radio Acoustic Sounding System (RASS), uses sound

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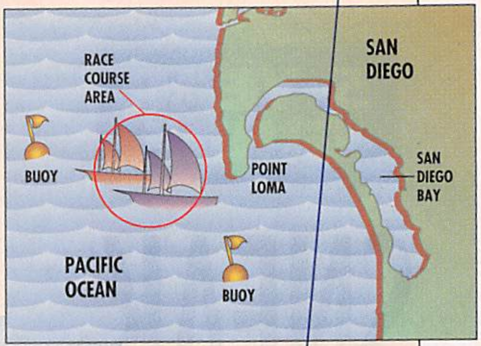
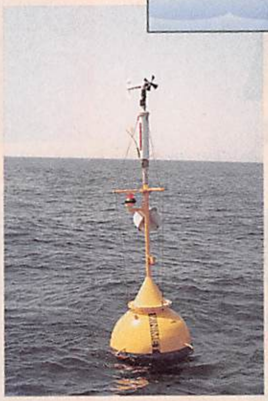
MESOSCALE FORECASTS FOR YACHTING



TOM WHITE

"The biggest weather mysteries are what's happening over the water during yachting races," says Chris Bedford, a meteorologist with Galson Corp. in East Syracuse, N.Y. To help solve such mysteries, the environmental consulting company has provided localized mesoscale weather forecasts for several America's Cup yachting competitions, including the 1987 Australian event ["Techno-yachts," Feb. '87]. Galson will aid the American team with local forecasts during the 1992 race in San Diego.

Data is collected at yachting sites and used in two ways, Bedford explains. First, to establish a long-term picture of off-shore weather, meteorologists may correlate on-shore readings with measurements made along the race course. "Wind conditions just a few miles off shore are drastically different from [those] right at the coast line," Bedford says. For the 1988 San Diego America's Cup race, Bedford used a computer to compare information from the nearby airport with data from Galson's offshore weather buoys. The company also used a Doppler acoustic sounder, called sodar, that beams ultrasonic sound waves into the atmosphere. Return echoes are analyzed to obtain wind speeds at low altitudes. An understanding of local wind patterns after studying all this data "allows designers to decide what type of boat they should be building for those conditions," Bedford says.



Sea buoys such as this one will supply weather data during the 1992 America's Cup race.

Local race course weather is also used for daily forecasts. Yachting teams often make crucial last-minute decisions based on forecast refinements. "The crew may change their sail inventory—headsails, spinnakers, or even the mainsail—to reflect a new forecast," explains Bedford. Mesoscale forecasts can only be used before the race; crews aren't allowed to receive information once they are under way.

Bedford also contributed to yacht-racing technology during the 1988 Bermuda Cup Challenge, a four-day race from Newport, R.I., to Bermuda. For that event, Galson teamed its meteorology expertise with other consultants familiar with geographic information systems, who provided detailed map data. Such map information can be manipulated with computers much like spreadsheets to enable a user to ask "what if" questions about columns and rows of numbers. To optimize a path to Bermuda within race course constraints, the team used four software packages and three computers to compare wind and ocean currents. The result? The third-place boat used the route they calculated, and the winner, using conventional methods, followed the same route.

In a more conventional research project, Galson helped others study the severe Lake Ontario snowstorms that can sneak in below existing—and NEXRAD—radars.
—*John Free*

5-YEAR GUIDE

SNEAK PEEKS AT THE IMPORT CARS TO COME

By JIM McCRAW

MODEL	1992	1993	1994	1995	1996	NOTES
ACURA						
Integra						
Vigor	Debuts w/ 5-cyl. engine				New model	
Legend				New model		4WD likely in '93
NSX	Minor changes					
ALFA-ROMEO						
Spyder 2000				New FWD/ 4WD coupe & roadster		
Milano		Redesigned				
164	Face lift & 4WD	Coupe added	4WD turbo	Face lift		
ASTON MARTIN LAGONDA						
Virage	Debuts				New small car	
Lagonda						
AUDI						
80/90	Convertible possible	New body	Wagon added		All new	
100/200	New body w/ 2.8L V6	New body	Wagon added		All new	New narrow-angle V6 also in VWs
V8	V8 wagon	New V8 sedan & coupe		All new		
BENTLEY						
Continental turbo R		6.7L V8				Bentley name is revived

waves to measure virtual temperatures—the temperature the air would be if the air was totally dry—up to approximately 18,800 feet. At an outdoor laboratory at Denver's Stapleton Airport where the RASS is being tested, my ears quickly detected a high-pitched screech. "Those are sound waves being propagated vertically from the acoustic loudspeaker, then tracked by a wind-profiling Doppler radar," explains electrical engineer and RASS researcher Richard Strauch. The enhanced radar not only measures wind velocity, it "looks" at the sound reflections as well.

Weather satellites are also equipped with sensitive temperature profile instruments, which look down from the satellites to the clouds below. By differentiating between observed temperatures, satellite scanners can distinguish between cloud types.

The government plan includes launching at least two high-altitude geostationary satellites before 1994. Three additional geostationary satellites, launched at intervals thereafter, are also planned. The total cost of the five satellites is approximately \$1.1 billion, budgeted separately from the NWS upgrade program. Improved cloud-temperature sensors and better cameras placed aboard the new satellites are expected to produce finer-detailed cloud pictures to help forecasters, although a technical problem encountered with the first satellite may limit the sensitivity of some of its sensors.

Costly inaccuracies?

While systems such as NEXRAD attract more attention, perhaps the most controversial component of the government's expensive weather modernization plan involves up to 1,700 Automated Surface Observing Systems (ASOS) units. These automated sensors will provide surface weather data for more accurate atmosphere simulation on forecaster's computers.

Each computer-linked ASOS will have an impressive array of sensors for wind speed and direction, temperature, dewpoint, atmospheric pressure and pressure-change trends, altimeter setting, visibility data in up to 10-mile increments, sky conditions (scattered, broken, or overcast up to 12,800 feet), and even a current-weather sensor to report the occurrence, amount, and intensity of rain, freezing rain, snow, and drizzle.

"The ASOS units are overly complicated," asserts Neal Marchbanks, a veteran Anchorage, Alaska-based meteorologist for the NWS. The equipment costs between \$100,000 and \$200,000. By contrast, a much simpler automated weather sensor that measures five basic weather conditions —wind speed and direction, pressure, temperature, and dewpoint—costs about \$25,000.

What's more, some ASOS sensors may not yet be reliable. The evidence: While being tested at the Tucson, Ariz., weather service site during the summer of 1990, the electronic ASOS thermometer may have incorrectly registered temperatures above the city's all-time maximum of 111°F on 15 different days.

Other ASOS-related reliability problems could be associated with what the units are being asked to do: replace human observers. For instance, the ASOS sensor for observing sky conditions only "sees" in one direction—straight up. "To have a flexible eye like a person, it would need robotics capability," Marchbanks argues. If the government's modernization plan is completed during the mid-1990s, it will cut the number of its weather offices from more than 200 to 115. The anticipated loss of human weather observers can't be fully compensated for simply by "adding NEXRADS and high-tech equipment," says Marchbanks.

Coverage gaps

But the strongest criticism against the new network of automated surface observers may be their proposed locations—exclusively at airports. "Putting the automated sensors at airports is very nice, but there are also areas that don't have airports where we could use some data," says meteorology professor Howard Bluestein of the University of Oklahoma.

The scarcity of surface data from remote areas is a nagging problem for meteorologists. "Any holes in the data set simply make for more guesswork," reports Morris Weisman, a severe-storms forecaster based in Boulder. Unfortunately, the government's weather services upgrade is structured around the NEXRAD radars, whose coverage limitations still can't supply weather data to remote areas.

"Modernization is NEXRAD-driven," says Peter Mandics, chief of the forecast systems division at the ERL. Although designed to maximize the benefits for as many as possible at the least cost, the new radar's coverage isn't all-inclusive. "Certain locations will be very far from the surrounding NEXRADs," Bluestein argues. As it stands, many remote low-population areas in high-risk severe-storm regions (especially in the Western United

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States) will remain relatively unprotected because of coverage gaps.

The solution may be a small-scale mesonetwork consisting of more economical automated systems that observe and report surface weather conditions. Such a network exists year-round in the Boulder-Denver vicinity, complementing a plethora of weather advances being used there. "Denver's experience highlights the value of having a mesonet," says Weisman.

But a mesonetwork in itself is not the entire solution. "The weakest link in the [weather services] system is still information management," Crawford says. How can an Elitch Gardens-type disaster be prevented? At present, the two best channels of transmitting timely weather information to the public are the federally sponsored weather radio and the Atlanta-based Weather Channel on cable television. Both broadcast continuous weather-related information and bulletins nonstop that many people can monitor.

Highway patrol monitoring

In Oklahoma, Crawford might have the closest thing to an answer. He's been the driving force behind an economical (\$2.7 million) soon-to-be implemented statewide mesoscale network of surface sensors. This network will not only be linked to Oklahoma's large weather-service infrastructure, but it will also be connected to a constantly monitored communications network so that timely weather information reaches people who need it most. "We'll have remote sensors, sharing data through the state highway patrol's telecommunications system and bringing the data back to the weather service offices. They'll use the data to prepare better forecasts and warnings, then the forecasts will go back out through that same system, reaching a central data-dissemination point," Crawford says.

Is there any chance that the Oklahoma program will catch on nationwide? Mandics is pessimistic. "The placing of surface observation networks is driven by population densities. The cost-benefit ratios probably don't favor dense surface observation networks in remote areas," he says.

But if the Oklahoma plan works and is widely adapted and linked with the NWS upgrade, by the year 2000 meteorologists might be able to make much more accurate forecasts and warnings. Then people once unfortunate enough to be in the wrong place at the wrong time, such as the victims in Plainfield and Denver's Elitch Gardens, could benefit from a weather forecasting revolution. PS